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Energy Procedia 5 (2011) 1172–1176

Energy Procedia

IACEED2010

Application of Improved Error GM (1, 1) Model on Predicting of Cultivated Land in Yiyang

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Abstract

Based on gray error GM (1,1) model, the paper proposed an improved error GM (1,1) model, and used this model to predict cultivated land in Yiyang. The results show that the improved error GM (1,1) model has high prediction accuracy, and better simulation results. And the results conform to the cultivated quantity change rule of Yiyang City, that is, the land area of Yiyang City, will appear in the next few years, modest growth trend, but the per capita arable land is still in the alert level of the United Nations. Therefore, protection of cultivated resources, rational utilization and protection of arable land are urgent tasks.

Keywords: Gray system; Gray Error Model GM (1,1); Cultivated Land Predicting

1. Introduction

The land resource is one of important and basic natural resources of the human survival and development. Cultivated land, as the essence of the land, provides the major part agricultural product and the light industry raw material for the humanity. That is to say, cultivated land resources and the utilization condition of cultivated land impact on the agricultural development and economical developing process, and its dynamic change and sustainable utilization undoubtedly impact regional sustainable development. Owing to the land data information is not complete, the defect is not strong regularity, using grey theory GM (1,1) model to forecast cultivated land, the simulation results are not satisfactory, and the prediction accuracy is not high. This paper applies the improvement the error GM(1,1) model to carry on cultivated land Predicting in Yiyang,and obtains better prediction results, then

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doi:10.1016/j.egypro.2011.03.205

discovered that its existence the question, proposes the optimized countermeasure, promotes the Yiyang cultivated land reasonable using.

2. Mechanism of gray modeling and improvement error GM(1,1) model

2.1. GM(1,1) Error Model

GM (1,1) model is a single sequence of first-order linear dynamic model, when the GM (1,1) model does not meet the requirements of accuracy, the residual sequence can be used to establish GM (1,1) model to modified the original model and improve the accuracy.

Setting $\varepsilon^{(0)}=[\varepsilon^{(0)}(1),\varepsilon^{(0)}(2),.....,\varepsilon^{(0)}(n)]$, where, $\varepsilon^{(0)}(k)$ is GM (1,1) model residual sequence. According to the grey theory, residual sequence GM (1,1) model is established, and gets $\hat{\varepsilon}^{(0)}(k+1)=(-a_\varepsilon)(\varepsilon^{(0)}(k_0)-\frac{b_\varepsilon}{a})e^{[-a_\varepsilon(k-k_0)]},k\geq k_0$, to $\hat{\varepsilon}^{(0)}(k+1)$ modified model as $\hat{x}^{(0)}(k+1)$, then the error correction time response equation is [1]:

$$\hat{x}^{(0)}(k+1)=\begin{cases}(-a)(x^{(0)}(1)-\frac{b}{a})e^{-ak},k<k_0\\(-a)(x^{(0)}(1)-\frac{b}{a})e^{-ak}\pm(-a_\varepsilon)(\varepsilon^{(0)}(k_0)-\frac{b_\varepsilon}{a_\varepsilon})e^{[-a_\varepsilon(k-k_0)]},k\geq k_0\end{cases} \quad (1)$$

2.2. Improved Error GM(1,1) Model

Making use of the data series to carry on GM (1, 1) model, when data does not meet the accuracy requirement, not all of the residual series are the residuals can be modelled residual final stage. Only then found k_0, satisfied:

①For any $k\geq k_0$, $\varepsilon^{(0)}(k)$ symbols consistent;

② $k_0\leq n-4$, residuals tail section $\varepsilon^{(0)}=(\varepsilon^{(0)}(k_0),\varepsilon^{(0)}(k_0+1),.....,\varepsilon^{(0)}(n))$ can be modeled. Therefore, error GM (1, 1) model improved method is to cancel these two conditions, such that for any residual sequence can be applied similar to the residual GM (1, 1) model to accurate treatment, is the absolute value of the residual series as the original series, to establish residual gray prediction model, and then apply the Markov process to determine when $k\geq n$ he residual value forecast symbols [2].

Setting $\varepsilon^{(0)}=[\varepsilon^{(0)}(1),\varepsilon^{(0)}(2),\cdots,\varepsilon^{(0)}(n)]$, where residual series:

$$\varepsilon^{(0)}(k)=\left|x^{(0)}(k)-\hat{x}^{(0)}(k)\right| \quad (2)$$

For the $X^{(0)}$, $\varepsilon^{(0)}$ build on GM (1, 1) model, we simulated sequence of residual tail section $\varepsilon^{(0)}$:

$$\hat{\varepsilon}^{(0)}=[\hat{\varepsilon}^{(0)}(1),\hat{\varepsilon}^{(0)}(2),.....,\hat{\varepsilon}^{(0)}(n)] \quad (3)$$

Where, $\hat{\varepsilon}^{(0)}(k+1)=(-a_\varepsilon)(\varepsilon^{(0)}(1)-\frac{b_\varepsilon}{a_\varepsilon})e^{(-a_\varepsilon k)}$

To $\hat{\varepsilon}^{(0)}(k+1)$ modified model as $\hat{x}^{(0)}(k+1)$, then improved error correction response time equation is: $\hat{x}^{(0)}(k+1)=(-a)(x^{(0)}(1)-\frac{b}{a})e^{-ak}+m(k+1)(-a_\varepsilon)(\varepsilon^{(0)}(1)-\frac{b_\varepsilon}{a_\varepsilon})e^{[-a_\varepsilon k]}$

Where, $m(k+1)=\begin{cases}1 & x^{(0)}(k+1)-\hat{x}^{(0)}(k+1)\geq 0\\-1 & x^{(0)}(k+1)-\hat{x}^{(0)}(k+1)<0\end{cases},k\leq n-1$ (4)

When $k\geq n$, $m(k+1)$ value needs to introduce the Markov process prediction. Owing to $m(k+1)$ has two states +1 and -1,the supposition error original state is: $S^{(0)}=[S_1^{(0)},S_2^{(0)}]$,where, $S_1^{(0)}$ is at the condition +1 original state (probability), $S_2^{(0)}$ is at the condition -1 original state (probability) [3].

According to the residual data state {+1,-1}, it finds out the state transition probability matrix P, determines the initial state $S^{(0)}$. According to the state transition equation $S^{(k+1)}=S^{(0)}P^{(k+1)}$, $k\geq n$

determines k+1 period m(k+1) status transfer results, and takes appear probability big state. If there is equal probability of positive and negative numbers, and generally the sign will be determined [4].

3. Example applications

3.1. Modeling and computation

This paper takes the primary data by the Yiyang 2000-2006 year 7 year cultivated area data information (Tab.1),uses GM(1,1) model and the improvement error GM(1,1) model separately to carry on the forecast to the cultivated area.

Tab.1. Cultivated Area in Yiyang (2000~2006)

Year	2000	2001	2002	2003	2004	2005	2006
Cultivated Area	24.57	24.44	24.57	24.32	23.27	24.06	24.79

Note: The above data from the Bureau of Yiyang City.

Using gray prediction theory, GM(1,1) year cultivated land forecast model is established, its foundation model is:

$$\begin{cases} \hat{x}^{(1)}(k+1) = -24576.5047e^{-0.000989k} + 24601.0747 \\ \hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \end{cases} \quad (5)$$

$\hat{x}^{(0)}(k+1)$ cultivated forecast model is $\hat{x}^{(0)}(k+1) = 24.32571e^{-0.000989k}$. Predicted results are listed in Tab.2. It makes use of improved error GM (1,1) model to built error forecasting model, where, $\hat{\varepsilon}^{(0)}(k+1)$ error forecasting model is $\hat{\varepsilon}^{(0)}(k+1) = 0.181715\ e^{0.19339(k-k_0)}$.

Synthesizing GM (1,1) forecasting model and the improvement error GM(1,1) forecasting model, it obtains the improvement error GM(1,1) cultivated land forecasting model:

$$\hat{x}^{(0)}(k+1) = 24.32571e^{-0.000989k} + m(k+1)0.181715e^{0.19339(k-k_0)},$$

the condition shift formula is:

$$S^{(k+1)} = (1,0)\begin{bmatrix} 2/3 & 1/3 \\ 1/2 & 1/2 \end{bmatrix}^{(k+1)} \quad k \geq n \quad (6)$$

To Use the improvement the double error GM(1,1) model build error forecasting model, where, $\hat{\varepsilon}^{(0)}(k+1)$ forecasting model is $\hat{\varepsilon}^{(0)}(k+1) = 0.169292e^{0.07379(k-k_0)}$ .Synthesizing GM(1,1) forecasting model $\hat{x}^{(0)}(k+1)$ and the improvement error GM(1,1) forecasting model $\hat{\varepsilon}^{(0)}(k+1)$,to obtain the final improved error GM (1,1) cultivated land forecasting model:

$$\hat{x}^{(0)}(k+1) = 24.32571e^{-0.000989k} + m(k+1)0.181715e^{0.19339(k-k_0)} + m(k+1)'0.169292e^{0.07379(k-k_0)} \quad (7)$$

the state transition equation as follows:

$$S^{(k+1)} = (1,0)\begin{bmatrix} 2/3 & 1/3 \\ 1/2 & 1/2 \end{bmatrix}^{(k+1)} \quad k \geq n', \quad S^{(k+1)} = (1,0)\begin{bmatrix} 1/2 & 1/2 \\ 2/3 & 1/3 \end{bmatrix}^{(k+1)} \quad k \geq n \quad (8)$$

Predicted by three models(see Fig.1),we can see that the residual data model and data model predicted double-residual curve close to the original curve, indicating that residual data model and double-residual prediction in this data model has the high feasibility in this forecast. The prediction accuracy of three prediction models in Tab. 2.

Tab. 2. Model precision analysis reference table

Model	Relative error α	Standard deviation ratio C_0	Small error probability p_0
GM(1,1)	0.01316	0.97	0.29
Error GM(1,1)	0.007751	0.55	0.71
Double-error GM(1,1)	0.005809	0.33	1

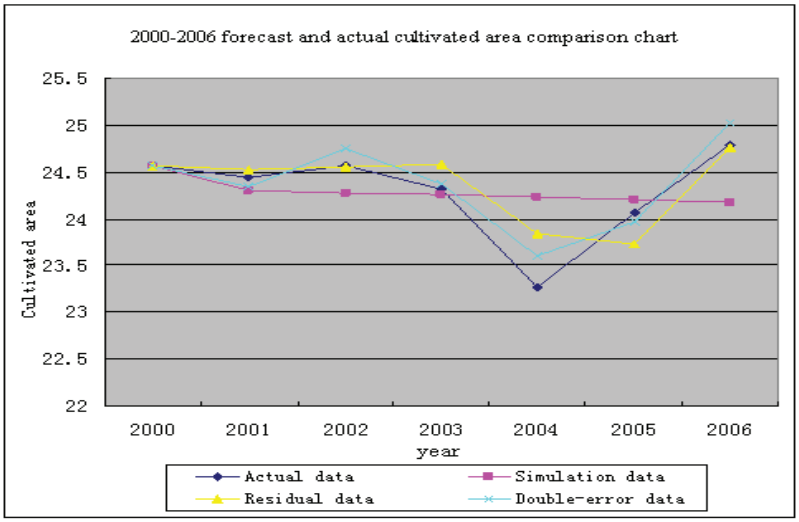

Fig.1. 2000-2006 forecast and actual cultivated area comparison chart

3.2. Forecast Analysis

To use population data in Yiyang (Tab.3) to predicted 2009-2012 year population. According to error GM (1,1) model and formula (7), it can predict 2009~2012 year cultivated land quantity, and obtain the average per person cultivated area number (listed in Tab.4).

Tab. 3. City population in Yiyang (2000～2008) （Unit: million）

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Population	450.47	453.16	454.69	456.51	458.54	460.60	463.00	465.25	467.66

Tab. 4. Predictive value of cultivated land area in Yiyang

Year	Population （million）	Cultivated Land Area (million hectares)	Average per person area (acres)
2009	469.81	25.15	0.80
2010	472.09	25.34	0.81
2011	474.38	25.59	0.81
2012	476.68	25.89	0.81

As can be seen from Tab.4,the actual amount of cultivated land increase slightly, while the projected amount of cultivated land is increasing year by year, and the number of actual and predicted land value of

cultivated land was close to the graph, indicating the general trend forecast is compared with the actual consistent. In addition, from the predicted value for each year of view, the error rates are relatively low, and to achieve an accuracy standard and the prediction is good. Overall, to use gray model to simulate the process of land change and prediction is feasible. Forecasting results are showed by Tab.4, in the next few years, the cultivated land total in Yiyang is still an increasing trend, but the average per person cultivated area is nearby United Nation's red line (≥0.8 Chinese acre), and lower than the our country average per person cultivated area (the land resources department issue 2006 year nation land utilization change survey result report that throughout our country present average per person farming has 1.39 Chinese acres.). It can be seen, the problem of cultivated land in Yiyang is unoptimistic, if the measure of conservation and protection of cultivated land is not positive adopted, and the future cultivated land issues in Yiyang City will be very severe. Therefore, strengthening the protection of cultivated land, carrying on sustainable development of cultivated land resources was still a next important work.

4. Conclusion

As can be seen from Tab.2, the revised test value of the improved model with a residual model was better than test value of GM (1,1) model, and the residual test value of the improved model reached the level. Improved gray error model is a convenient and reliable method. In addition, this article, based on cultivated land over the years in Yiyang, established GM (1,1) model to forecast cultivated land change situation in the future several year in Yiyang. But from a long-term forecasting, the model is based on only 7 groups of data; it is difficult to predict the combined effects of various factors for the general analysis. Therefore, we must take into account the accuracy of the model test, and must enable the establishment the model to reflect that the more change combined action factors, enables the establishment the model to have representative, concise as well as forecast long time precision reliable, when predicting. Improved error GM(1,1) model will make the results more scientific, more practical, and provides the scientific basis for the production, if GM (1,1) prediction model and the traditional prediction method (such as return forecast and department forecast) as well as local realities are Considered together, when establishing GM (1,1) model.

Acknowledgements

This work was supported by Hunan city university youth fund. (07B007)

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